RESEARCH PAPER

Ultrasonographic Evaluation of Fetal Biometric Parameters for Gestational Age Estimation in Second Trimester Pregnancy: A Cross-Sectional Study

[1] Bharati Ghotane, [2*] Archana V Salunkhe, [3] Prafulla Dakhane, [4] Priya Patil, [5] Vasudha Nikam

[1]Assistant Professor, Department of Anatomy, Prakash Institute of Medical Sciences, Islampur, India
[2*]Associate Professor, Department of Anatomy, Bharati Vidyapeeth (Deemed to be University) Medical College and Hospital, Sangli, India. Email: dr.archanasalunkhe.as@gmail.com
[3]Professor and Head, Department of Anatomy, Dr. Vasantrao Pawar Medical College and Research Center, Adgaon, Nashik, India
[4]Professor, Department of Anatomy, Bharati Vidyapeeth (Deemed to be University) Medical College and Hospital, Sangli, India
[5]Professor, Department of Anatomy, D.Y. Patil Medical College and Hospital, Kolhapur, India
Corresponding author: Dr. Archana Vishwasrao Salunkhe, Associate Professor, Bharati Vidyapeeth (Deemed to be University) Medical College and Hospital, Sangli, India

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ABSTRACT

Background: roper estimation of gestational age is crucial in the process of effective prenatal care and obstetric control. Ultrasonography is a good method of measuring fetal biometrics in order to estimate the gestational age of a pregnancy.

Objective: To determine reference values of the fetal biometric measurements of biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) during the second trimester and determine the relationship between these variables and gestational age.

Materials and Methods: 350 healthy pregnant women aged 14-27 weeks of gestation that were visiting the Department of Radiology were studied in a cross-sectional study. Measurement of BPD, HC, AC, and FL was carried out with the help of real-time ultrasonography through the usage of linear array transducer. Women pregnant more than once, with illnesses in the maternal tract, doubtful last menstrual period, or fetal anomalies were excluded. Statistical analysis involved determination of mean, standard deviation, correlation and unpaired t -test.

Results: All the four biometric parameters depicted a linear increase with the increasing gestational age. The results of BPD varied between 23-73 mm (mean: 50.91+38.26 mm), FL between 10-53 mm (mean: 34.05+12.06 mm), AC between 62-229 mm(mean: 152.27+51.8 mm) and HC between 82-268 mm (mean: 179.51+51.8 mm). The BPD-HC (r=0.4), BPD-AC (r=0.41), BPD-FL (r=0.405), HC-AC (r=0.925), HC-FL (r=0.949), and AC-FL (r=0.957) were found to be strongly positively correlated with each other. All the correlations were significant (p<0.001).

Conclusion: Ultrasonographic fetal biometry has good correlation with gestational age during the second trimester. The multiple parameters used together with each other lead to better accuracy of estimation of gestational age. The developed reference values are good indices to clinical obstetric practice within the population of the region.

Keywords: Ultrasonography, Fetal biometry, Gestational age, Biparietal diameter, Femur length, Second trimester

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INTRODUCTION

Proper assessment of gestational age is one of the pillars of contemporary obstetric practice, as it plays a crucial part in making important decisions related to prenatal care, diagnosis of growth abnormalities, intervention schedule, and optimal birth planning.[1-3] Although the traditional approaches of gestational age estimation, including the last menstrual period (LMP) and physical examination, offer varying estimates, ultrasonography is regarded as the most accurate and reproducible technique of gestational age estimation, as it features precise measurements of fetal anatomical structures.[4] The second trimester of pregnancy duration (14-27 gestation) has provided a best time frame to conduct biometric assessment. Fetal structures at this stage are well formed to be studied clearly and the biological variations are still quite limited compared with the third trimester and therefore ultrasonographic evaluation at this stage not only allows the accurate determination of date but also provides the overall examination of the fetus anatomy, as well as growth evaluation.[5,6] Several fetal biometrical measures have been confirmed to predict gestational age. Biparietal diameter (BPD), which is the greatest transverse diameter of the fetal skull, has the strongest correlation with gestational age during the second trimester.[7-9] Head circumference (HC), which is typically used to assess growth, offers useful data in the determination of gestational age.[10,11] Abdominal circumference (AC), the other parameter that shows good use in gestational age determination, is used to measure the skeletal development.[12,45-52] A combination of several biometric parameters leads to a significant increase in the level of predictability. It has been shown that joint measurements minimize the error of estimation by about a quarter as compared to single level techniques.[13,14,] and multiple anatomical planes are systematically evaluated to detect structural abnormalities, which achieve the goals of both dating and screening.[15] The geographical, ethnic, and nutritional deviations have effects on pattern of fetal growth, which has to be compared to population-specific reference standards, and the international standards serve as more of a guideline only, whereas the local reference curves contribute to the greater applicability of clinical use and less ambiguity in diagnosing fetal gestational age. Although much research has been conducted about fetal biometry in the world, there are very few sources about Indian population, especially on the regional centers. The current research was intended to set reference values concerning BPD, HC, AC, and FL measurements at the second trimester in a local population, to assess the relationships of these variables as well as compare the results with available international standards. The study offers clinically significant information to assess gestational age correctly and to the existing literature of population-specific biometric research.

MATERIALS AND METHODS

Study Design and Setting

This cross-sectional observational study was conducted at the Department of Radiology, Dr. D. Y. Patil Medical College and Hospital, Kadamwadi, Kolhapur, Maharashtra, India, following approval from the institutional ethical committee. The study period, during which pregnant women attending the antenatal clinic were consecutively recruited.

Study Population and Sample Size

A total of 350 healthy pregnant women in the second trimester (14-27 weeks gestation) were included in the study. Sample size calculation was based on previous similar studies, ensuring adequate representation across each gestational week. Women were recruited consecutively to minimize selection bias.

Inclusion Criteria

The study included pregnant women meeting the following criteria:

- Gestational age between 14-27 completed weeks based on reliable last menstrual period
- Singleton pregnancy confirmed by ultrasonography
- Accurate menstrual history with regular menstrual cycles
- No maternal medical complications
- Normal nutritional status
- Willingness to participate and provide informed consent

Exclusion Criteria

Women meeting any of the following criteria were excluded from the study:

- Multiple pregnancies (twins, triplets, or higher order)

- Maternal diabetes mellitus (pre-existing or gestational)
- Maternal hypertension or pre-eclampsia
- Moderate to severe maternal anemia
- First pregnancy at age 30 years or above
- Ambiguous or uncertain last menstrual period
- Detectable fetal anomalies on ultrasonography
- Previous history of intrauterine growth restriction
- Maternal smoking or substance abuse

Ultrasonographic Examination

All the ultrasonographic studies were conducted on the basis of real-time B-mode ultrasonography using linear array sector transducer with 3-5 MHz. Examinations were done with the mother lying in supine position and full urinary bladder to ensure optimum acoustic window. To make transmission of ultrasonic waves effective, coupling gel was placed between the abdomen of the mother and the transducer surface.

Biometric Measurements

A standardized protocol was followed for obtaining fetal biometric measurements:

Biparietal Diameter (BPD): The BPD was measured at the thalami and cavum septi pellucidi, which is the greatest transverse diameter of the fetal skull. This was measured between the outer edge of proximal skull table and the inner edge of the distal skull table.20 Head Circumference (HC): This is a measurement taken at the same axial plane as is taken in measuring BPD, but omitting the cerebellum[15-20].

Head Circumference (HC): Measured by tracing the outer margin of the calvarium at the same axial plane used for BPD measurement, excluding the cerebellum.[21]

Abdominal Circumference (AC): Obtained at the level of the junction of the umbilical vein and portal sinus, visualizing the stomach bubble and visualizing a circular abdominal contour.[22]

Femur Length (FL): Measured as the length of the ossified femoral diaphysis, from the major trochanter to the lateral condyle, using the longest straight longitudinal axis.[23]

Each measurement was performed three times and the average value was recorded to minimize measurement error. All examinations were performed by experienced radiologists to ensure consistency and reliability.

Anatomical Survey

A comprehensive anatomical survey was performed during each examination to confirm fetal normality:

- **Fetal head:** Assessment of cerebral cortex, lateral ventricles, cavum septi pellucidi, thalami, and cerebellar hemispheres
- **Thorax:** Evaluation of four-chamber cardiac view and lung echogenicity
- **Abdomen:** Visualization of stomach, liver, kidneys, and umbilical cord insertion
- **Spine:** Assessment of spinal integrity in longitudinal and transverse planes
- **Skeletal system:** Examination of long bones for proper development
- **Placenta:** Localization of placental position and assessment of amniotic fluid volume

Data Collection and Management

Demographic and clinical data including maternal age, parity, last menstrual period, and medical history were recorded on standardized proforma. Ultrasonographic measurements were documented immediately following examination. Data were entered into Microsoft Excel spreadsheets and subsequently transferred to statistical software for analysis.

Statistical Analysis

The analysis was done statistically through the application of specific software. All biometric parameters in each week of gestation were calculated based on descriptive statistics such as mean, standard deviation, range, and frequency distributions. Pearson correlation coefficient was calculated to check the correlation among various biometric parameters. Statistical significance of differences of unpaired t-test with Welch correction were used. There was a multiple regression analysis that was conducted to create predictive equations that could be used to estimate the gestational age. A p-value that was below 0.05 was regarded as statistically significant.

Ethical Considerations

The Institutional Ethics Committee gave consent to the study protocol. Informed consent was received in writing through the explanation of the study objectives, procedures, risks, and benefits to all the participants. The confidentiality of patient information was ensured. As a component of normal antenatal care, there was no extra expense on ultrasonographic procedures.

RESULTS

Demographic Characteristics

The study included 350 healthy pregnant women between 14-27 weeks of gestation, with 25 cases examined at each gestational week. All participants had singleton pregnancies with reliable menstrual dates and no maternal complications or fetal anomalies detected on ultrasonographic examination.

Biparietal Diameter (BPD)

Biparietal diameter measurements demonstrated consistent linear growth throughout the second trimester. The overall range extended from 23 mm at 14 weeks to 73 mm at 27 weeks, with a mean value of 50.91±38.26 mm across all gestational ages.

Table 1: Weekly mean values and range of Biparietal Diameter (BPD) from 14-27 weeks

Gestational Age (weeks)	Mean (mm)	Standard Deviation	Range (mm)
14	26.25	1.79	23-29
15	30.74	1.47	29-35
16	35.06	1.60	31.9-38
17	38.22	2.54	31-44.7
18	42.22	2.09	39-46
19	45.50	1.79	43-51
20	47.65	2.24	43-53
21	50.94	2.11	46-55
22	53.82	1.78	50-57
23	56.29	0.57	55-57.3
24	59.90	1.55	56-62
25	63.92	0.80	63-66
26	66.80	0.96	65-69
27	72.07	0.53	71-73

Maximum weekly increase in BPD was observed at 25-26 weeks (3.12 mm), followed by 14-15 weeks (4.49 mm) and 15-16 weeks (4.32 mm). The minimum weekly increment occurred at 19-20 weeks (2.15 mm).

Head Circumference (HC)

Head circumference measurements showed progressive increase from 94.28±6.97 mm at 14 weeks to 261.40±4.18 mm at 27 weeks. The overall mean across all gestational ages was 179.51±51.8 mm.

Table 2: Weekly mean values and range of Head Circumference (HC) from 14-27 weeks

Gestational Age (weeks)	Mean (mm)	Standard Deviation	Range (mm)
14	94.28	6.97	82-106
15	110.12	3.67	100-115
16	128.13	5.39	117-138
17	139.97	4.87	131-151
18	155.58	7.60	140-172
19	164.65	4.91	152-173
20	174.88	7.64	160-190
21	189.23	6.61	175-200
22	199.94	5.41	189-210
23	211.94	5.35	201-224
24	220.61	6.50	208-230
25	233.74	2.87	230-240
26	243.80	2.83	237-249

27	261.40	4.18	254-268

Maximum weekly increase occurred at 15-16 weeks (18.01 mm) and 26-27 weeks (17.60 mm), while minimum increment was noted at 24-25 weeks (13.13 mm).

Abdominal Circumference (AC)

Abdominal circumference demonstrated consistent growth from 76.04±5.54 mm at 14 weeks to 227.28±0.98 mm at 27 weeks. The mean value across all gestational ages was 152.27±51.8 mm.

Table 3: Weekly mean values and range of Abdominal Circumference (AC) from 14-27 weeks

Gestational Age (weeks)	Mean (mm)	Standard Deviation	Range (mm)
14	76.04	5.54	62-84
15	94.48	1.33	92-97
16	104.10	7.90	91-134
17	111.80	5.17	97-121
18	129.31	8.77	110-145
19	136.16	5.29	127-145
20	145.15	6.99	132-156
21	160.98	12.25	145-187
22	171.05	2.41	167-178
23	182.51	1.24	180-185
24	192.16	2.75	189-200
25	202.29	3.28	196.7-210.3
26	214.44	1.64	211-218
27	227.28	0.98	226-229

Maximum weekly increment occurred at 14-15 weeks (18.44 mm) and 17-18 weeks (17.51 mm), with minimum increase observed at 18-19 weeks (6.85 mm).

Femur Length (FL)

Femur length measurements ranged from 13.81±1.69 mm at 14 weeks to 52.04±0.84 mm at 27 weeks, with an overall mean of 34.05±12.06 mm.

Table 4: Weekly mean values and range of Femur Length (FL) from 14-27 weeks

Gestational Age (weeks)	Mean (mm)	Standard Deviation	Range (mm)
14	13.81	1.69	10-18
15	18.38	1.33	14-20
16	21.23	1.23	19-24
17	24.18	1.40	21-26
18	27.67	1.78	26-33
19	31.17	2.07	28-36
20	32.35	2.06	29-37
21	35.80	1.10	34.7-39
22	39.35	1.06	38-41.5
23	42.00	0.79	41-44
24	44.66	1.05	43-46.7
25	47.74	1.18	46-50
26	49.34	0.67	48-50.1
27	52.04	0.84	51-53

Maximum weekly increase occurred at 14-15 weeks (4.57 mm), with minimum increment at 19-20 weeks (1.18 mm).

Correlation Analysis

Strong positive correlations were observed between all biometric parameters, indicating their interdependent growth patterns during the second trimester.

Table 5: Correlation coefficients between different biometric parameters

Parameter Combination	Correlation Coefficient (r)	P-value
BPD - HC	0.400	<0.0001
BPD - AC	0.410	<0.0001
BPD - FL	0.405	<0.0001
HC - AC	0.925	<0.0001
HC - FL	0.949	<0.0001
AC - FL	0.957	<0.0001

Statistical analysis using unpaired t-test demonstrated that all parameter combinations were highly significant ($p<0.0001$), confirming their strong relationships and reliability for gestational age estimation.

Comparative Analysis with Maximum and Minimum Increments

Analysis of weekly growth patterns revealed distinct periods of maximum and minimum growth for different parameters:

Table 6: Gestational weeks showing maximum and minimum parameter increments

Parameter	Maximum Increase	Minimum Increase
BPD	25-26 weeks	19-20 weeks
HC	15-16 weeks	24-25 weeks
AC	14-15 weeks	18-19 weeks
FL	14-15 weeks	19-20 weeks

DISCUSSION

The current research provides extensive reference values of four fetal vital biometric measurements in the second trimester in a local group of people. We have shown that BPD, HC, AC and FL have steady linear growth patterns as gestational age advances and that there are significant correlations between all the parameters, which confirms their usage as a combination to be used to accurately estimate gestational age.

Biparietal Diameter Analysis

The parameter that has been most studied with regard to gestational age assessment during the second trimester is Biparietal diameter which is determined to range between 26.25 mm at 14 weeks and 72.07 mm at 27 weeks in our study. These are measurements that are in close agreement with the international standards but with slight variations, which can be explained by the population-specific factors. When compared to other studies made before, some interesting patterns are noted. According to Hadlock et al. (1984), the values of BPD were 25.63 mm at 14 weeks and 68.1 mm at 27 weeks,[21-26] slightly weaker than those of us. Likewise, BPD measurements of 28 mm at week 14 and 67.01 mm at 27 weeks,[27] were recorded by Kawin Kankeow et al. (2007), and it is close to our data. McGregor et al. (2008) and Daniel Salpou et al. (2008) however, found more slightly higher values especially during the mid-second trimester,[28,29] implying, possibly, ethnic or geographical differences. Our study found that the greatest increase in BPD was at 25-26 weeks (3.12 mm/week) and then early second trimester was at 14-15 weeks. This biphasic pattern of growth signifies the dynamic nature of cranial development of fetus with fast early growth and a second acceleration phase occurring in late second trimester. The smallest increase was in 19-20 weeks (2.15 mm) which was a transitional period in skull development.

Head Circumference Evaluation

The head circumference is a good substitute to BPD, especially when skull shapes such as dolichocephaly or brachycephaly disrupt the accuracy of the BPD.30,31 HC between 14-27 weeks showed a smooth developmental pattern, and these values were between 94.28mm and 261.40mm. A comparison with Hadlock et al. (1982) indicates that we have relatively lower values in early second trimester but similar values in late second trimester.[28-32] Kawin Kankeow et al. (2007) examined the values of HC at 14 weeks and 27 weeks and found that the values are always lesser than ours.[27] This difference can be attributed to the differences in the methods of measurement, calibration of the equipment, or actual population-specific growth trends. This is because BPD and HC are strongly correlated (r=0.400), indicating that HC is an integrative parameter that is highly correlated with it, whereas HC is also very correlated with AC (r=0.925) and FL (r=0.949), indicating that HC is an excellent integrative parameter, which measures the overall fetal growth.

Abdominal Circumference Assessment

Abdominal circumference, while primarily utilized for fetal weight estimation and growth assessment, contributes significantly to gestational age determination.[33,34] Our AC measurements demonstrated substantial variation, ranging from 76.04 mm at 14 weeks to 227.28 mm at 27 weeks.

The maximum weekly increment occurred at 14-15 weeks (18.44 mm), reflecting the rapid development of intra-abdominal organs during early second trimester. Comparison with previous studies shows our values intermediate between those of Hadlock et al. (1984) and local studies by Kawin Kankeow et al. (2007).[26,27]

The exceptionally high correlation coefficients observed between AC and other parameters (AC-HC: r=0.925; AC-FL: r=0.957) confirm its reliability as a biometric indicator. These strong relationships validate the inclusion of AC in multiple-parameter gestational age estimation models.

Femur Length Analysis

Femur length provides an excellent skeletal maturity indicator, relatively independent of fetal nutritional status compared to soft tissue measurements.[35,36] Our FL measurements ranged from 13.81 mm at 14 weeks to 52.04 mm at 27 weeks, showing linear progression with minimal variation.

Comparison with international standards reveals close concordance. Hadlock et al. (1984) reported FL values from approximately 14 mm at 14 weeks to 51.4 mm at 27 weeks,[26] nearly identical to our findings. This remarkable similarity across different populations suggests FL may be less influenced by ethnic or geographical factors compared to other biometric parameters.

The maximum weekly increment in FL occurred at 14-15 weeks (4.57 mm), representing the period of maximum long bone elongation. The minimum increment at 19-20 weeks (1.18 mm) may reflect a physiological deceleration phase before the third trimester growth spurt.

Correlation Between Parameters

The strong positive correlations observed between all parameter pairs (r ranging from 0.400 to 0.957) confirm the coordinated nature of fetal growth. The highest correlation was observed between AC and FL (r=0.957), followed by HC-FL (r=0.949) and HC-AC (r=0.925). These relationships validate the use of multiple parameters for enhancing gestational age estimation accuracy.

Previous studies have consistently demonstrated that combining multiple biometric parameters reduces estimation error by 25-30% compared to single-parameter approaches.[37,38] The strong correlations in our study support this principle, suggesting that integrated assessment using all four parameters provides optimal accuracy for gestational age determination.

Population-Specific Variations

Comparison of our findings with international and regional studies reveals both similarities and differences. While basic growth patterns remain consistent across populations, absolute values show variations that may reflect ethnic, nutritional, or genetic factors.[39,40] These observations underscore the importance of developing population-specific reference standards rather than relying exclusively on international normative data.

Studies from different Indian regions have reported varying biometric values, supporting the need for regional standards.[41,42] Our data from Western Maharashtra provides clinically relevant reference values for this geographical area, potentially improving diagnostic accuracy in local obstetric practice.

Clinical Implications

The findings of this study have several important clinical implications:

1. **Enhanced Dating Accuracy:** Combined use of BPD, HC, AC, and FL provides robust gestational age estimation, particularly beneficial when LMP is uncertain
2. **Growth Assessment:** Established reference ranges enable early detection of intrauterine growth restriction or macrosomia

3. **Anomaly Detection:** Systematic evaluation of multiple anatomical planes facilitates early identification of congenital anomalies
4. **Regional Relevance:** Population-specific data improves clinical decision-making in local obstetric practice
5. **Quality Assurance:** Standardized measurement protocols ensure consistency and reproducibility across different operators

Safety Considerations

Ultrasonography has been extensively evaluated for safety in pregnancy, with no confirmed adverse biological effects at diagnostic intensities.[43,44] Multiple large-scale studies including those by Torloni et al. (2009) have confirmed that diagnostic ultrasound does not adversely affect maternal or perinatal outcomes, physical development, neurological development, or intellectual performance.[45] This safety profile supports routine use of ultrasonography for biometric assessment.

Limitations

Several limitations of this study merit consideration:

- Cross-sectional design limits assessment of individual growth trajectories
- Exclusion criteria may limit generalizability to high-risk populations
- Single-center study may not fully represent broader regional or national patterns
- Inter-observer variability, though minimized by experienced operators, cannot be completely eliminated
- Follow-up to delivery outcomes was not included in the current study design

Future Directions

Future research should focus on:

- Longitudinal studies following individual fetuses throughout pregnancy
- Incorporation of additional parameters such as transcerebellar diameter and orbital measurements
- Three-dimensional and four-dimensional ultrasonography applications
- Artificial intelligence and machine learning algorithms for automated biometric analysis
- Multi-center studies to establish comprehensive national reference standards
- Correlation of biometric measurements with neonatal anthropometry and outcomes

CONCLUSION

Such a detailed research provides valid reference values of fetal biometric parameters during the second trimester of pregnancy. The ultrasonographic assessment of BPD, HC, AC, and FL has linear growth patterns with good inter-correlations justifying their combined use to estimate gestational age correctly. The relationships among all four parameters are statistically significant ($p<0.001$), which testifies to the reliability of these parameters as the indices of fetal development assessment. The research concludes that ultrasonography is a dual diagnostic and therapeutic tool in obstetric practice, which could be used not only to determine the gestational age but also to perform a complete anatomical scan and identify abnormalities in the early stages of pregnancy. The method of systematic examination with a combination of several measurement plans guarantees a comprehensive assessment of the fetal structures without compromising the level of safety. The reference values developed in this research based on population-specific features offer clinically valuable data on obstetric management of the local population. Although general development trends are consistent with international standards, minor differences can be seen to support the significance of local reference curves towards the highest diagnosis accuracy. These high-r correlations among the parameters (BPD-HC: $r=0.4$; BPD-AC: $r=0.41$; BPD-FL: $r=0.405$; HC-AC: $r=0.925$; HC-FL: $r=0.949$; AC-FL: $r=0.957$) confirm the principle that a multidimensional approach to assessment predictability is greater than the performance of the single-parameter methods. The combination of both will minimize errors in estimations and offer more valuable clinical data to guide prenatal care planning. Further studies with longitudinal designs, improved imaging systems and correlation with delivery results would also help us better understand the dynamics of fetal growth and help optimize obstetric care provision. When national databases including regional variations will be established, the long-term effect is the enhancement of standardization and quality of prenatal care across different populations.

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